ISSN: 2321 – 7537
IJEDST (2017), 5(1):1-6

New Efficient Method for Engineering Education Analysis and Implementation

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ABSTRACT:
New efficient methods for teaching engineering have attracted the attention of most faculty members in engineering education. The aim of this paper is to address the research question: Does the current methods used for teaching engineering enable learners to develop desirable professional engineering skills? To find an answer for this question we need to discuss the knowledge and skills achieved with classical methods. Nowadays, the results show some drawbacks in engineering education systems. This paper proposes a new teaching method to improve required knowledge and skills of graduated students. The proposed method is discussed in details to show its effectiveness on the performances of students.
Key words: Engineering education, Active methods, teaching in laboratory, high thinking skills.

INTRODUCTION

The engineering education in the world is developed progressively in aim to achieve required goals and objectives [1]-[4]. The development of the teaching and assessment methods is generally related to both needs and development in technology and industrial fields [4]-[8]. To analyze the teaching methods and propose improvements or new strategies, many research works were published in last decade [5]-[8]. Also, faculty members in engineering colleges and technical universities are implicated in this domain. Moreover, engineering faculty members are interested by developing their teaching strategies and methods. The methods used currently can be classified to four types; passive, active, learner oriented and teacher oriented [9]-[11]. Literature in education shows that passive method allows poor outcomes in terms of both skills and knowledge [9], [12], [13].

In fact, this method is based only on lower thinking skills where instructors transmit knowledge to students in a brief time. In such method, students are not involved in higher learning skills such as analyzing or applying the new concept learned. This lead to graduates who are not able to analyze and design new solutions for complex engineering problems.

The active method allows freedom for instructor to invite students to participate in the development of the course design [14]-[16]. This method is developed to be classified as learner oriented and teacher oriented methods. The first one is called also student driven model where the instructor take the role of the coach and gives more control of learning process to the student [16]. Consequently, the method can be easily adapted to address expected learning outcomes of engineering programs such as the ABET(Accreditation Board for Engineering and Technology) criteria. In addition the feedback of graduates shows the necessity to develop new methods for teaching engineering. This paper investigates the development of a new method for engineering education. Section II is consecrated to a brief presentation of the goals, objectives and learning outcomes in the field of engineering education. The proposed method based on teaching in the laboratory is presented and discussed in section III. In section IV, the learning based on high thinking skills is presented and discussed. The proposed method is adopted to satisfy the conditions of learning based on high thinking skills. Conclusion and perspectives are summarized in section V.

ABET CRTERION AND LEARNING OUTCOMES

Meeting ABET requirements

ABET is a nongovernment organization developed a high education standards that focus on what students experience and learn.

To satisfy one of the most important ABET criterions, the learning outcomes must be written

ISSN: 2321 – 7537
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effectively. Indeed, the first step of the preparation of the course is the determination of the learning objectives. After the identification of learning objectives the knowledge and skills will be listed and prepared.

Student Outcomes are statements that clarify what students are expected to be able to do by the time of graduation. They are related to skills and knowledge that students will acquire through the program.

According to ABET, the student outcomes of the Electrical engineering program are:
a- Apply knowledge of mathematics, science, and engineering
b- Design and conduct experiments, as well as to analyze and interpret data
c- Design a system, component, or process to meet desired needs
d- Function on multi-disciplinary teams
e- Identify, formulate, and solve engineering problems
f- Understand professional and ethical responsibility
g- Communicate effectively
h- Acquire the broad education necessary to understand the impact of engineering solutions in a global and societal context
i- Recognize the need for, and be able to engage in life-long learning
j- Acquire knowledge of contemporary issues
k- Use the techniques, skills, and modem engineering tools necessary for engineering practice

Learning Outcomes
Courses objectives are a general statement to describe what a faculty member will cover in a course. However, the learning objectives or learning outcomes (LO) is a simple statement of what you expect your students to know. A LO is also defined as a detailed description of what a student must be able to do at the end of a course or lecture. To prepare an effective planning of a course we need to determine the most important learning objectives. A good method to determine correctly the learning objectives is to ask our selves "What do students need to know in order to derive maximum benefit from this educational experience? For this essential goal, educators around the world deliver and assist the educational courses based on the level of thinking needed for learning. One example for such classification of level of thinking is the Bloom's taxonomy. This taxonomy helps faculty members to write effective learning objectives. Bloom's taxonomy was created in 1956 under the leadership of educational Psychologist Benjamin Bloom from Chicago University. This taxonomy is defined as multitude model to classify thinking according to six cognitive domains. The important task is to associate actions verbs with each level of thinking in Bloom's taxonomy. The next section will focus on the description of thinking skills in more details.

Bloom's taxonomy
As we have explained, Bloom's taxonomy allows classifying the thinking levels according to six cognitive domains. Fig. 1 shows the organization of the six levels of Bloom's taxonomy. In each level, we will describe some of the activities or learning techniques that can be used to support the learning process in each level of Bloom's taxonomy.

Remembering is the lowest level of thinking in Bloom's taxonomy. It involves the retrieve and the recall of a new knowledge from long and short term memory. Remembering level is the first level of learning and this will be the first level that student encounter in the process of learning. The objective is to make students remember new knowledge and skills. If students are not able to remember this new knowledge, student will not be able to reach the second level of thinking which is understanding. Many activities can be proposed in this level to make students with strong memory. Hence, if we introduce novel knowledge for students, we can ask them immediately to call this new knowledge. The objective is to cheek if the new knowledge was memorized by students.

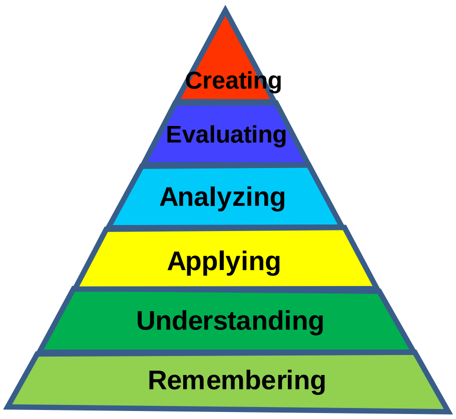

Fig.1. Levels of thinking according to Bloom's taxonomy

The second level concerns the understanding witch deals with the ability to grasp the meaning of previously learned materials. Some of the activities that can be associated with this level are interpreting materials, explaining or summarizing some results. The third level of bloom's taxonomy is applying

learned concept of the understand materials. It deals with the ability to apply learned knowledge in new situations. The activities are many at this level. The objective is to make students able to apply the new knowledge and skills like rules, methods, concepts, principles and theories. The fourth level in Bloom's taxonomy is the analysis of the existed methods and theories. This may include the identification of the parts of a given system and the analysis of the relationships between parts. The fifth level is the evaluation. Evaluate an existing solution allows to assess it. It involves the ability to judge the value of materials for a given purpose. In engineering education, the evaluation level may be related to the evaluation of the performances of a given system. This level of thinking consists to a preparation for the higher level of thinking. Once we determine the advantages and disadvantages of the analyzed subject in the analysis level, we can move to the evaluation level. This is the higher level of thinking witch is creating and inventing new products and solutions. To explain more those levels of thinking, the following example relates Bloom's taxonomy to the history of the linear machines invention.

History of the invention of linear machines
Any development and invention in the field of engineering seems to be advanced according to Bloom's taxonomy. The remembering step consists of recalling the main elements like rotor and stator. The understanding involves the description of the principle of operation of rotary machine and equivalent model. The applying level consists of the utilization of different methods and rules to find the power, the losses, and the efficiency of this method. Analyzing level consists of analyzing the efficiency of these machines in industrial applications requiring linear displacement and linear forces. The evaluation allows judging the performances of rotary machines linear displacement application. The low efficiency in the power transmission and the conversion of rotary movement to linear movement requires development of the new linear machines.

NOVEL STRATEGY FOR ENGINEERING TEACHING

Problems related to classical methods of teaching
To analyze existing methods of teaching, it is very important to analyze the feedbacks results that show some insufficiency on the students' skills. The feedback results show the necessity of developing new methods for teaching and engineering education. Generally, in engineering education, every course consists of three parts; the lecture, the tutorial and the laboratory. In the lecture part, the instructor presents and discusses the new knowledge in a given topic. Some examples are solved in the same lecture. The tutorial is usually consecrated on solving some problems related to the same topic. Finally, the laboratory exercises are achieved in the same topic based on our experience in electrical engineering education, the instructors and the learners encounter or might encounter some of the following problems:

- Sometimes, the lectures and the labs are not synchronized, in such cases, the student might start the lab before studying the concept in the lecture class.
- Students study the theoretical many weeks before the labs. They forget every think in the lab. The laboratory instructor will revise all knowledge before starting the laboratory exercises. The drawback is the losses in time.

Description and presentation of the new method
The proposed method uses a teaching technique that is based on the high thinking levels. Indeed, the course is taught in the laboratory. The instructor will use all equipment and computers in the laboratory to make students thinking about some theories. The objective of this method is to encourage students to think about knowledge and memorize all novel knowledge. In the presented paper we describe a scenario for teaching power electronics in the laboratory. This scenario consists of six steps.

Step 1: Using the equipment in the laboratory
The instructor should present a problem when we have a DC machine and an AC power system. The question should be: How can we supply the DC machine by AC power system. Indeed, when we connect the DC machine to an AC power system, the machine does not work. The instructor guides the student to reach this result.

Step 2: Using software for the simulation of rectifier
The second step in this scenario consists of the simulation of the power converter using special software and a computer. In this stage the student who conducts the simulation discovers the symbols of all power semiconductor devices. Also, student should measure and identify the voltages in the input and the output of the converter. He discovers the necessity of this converter for the conversion of AC voltage to DC voltage. Many other activities can be proposed and discussed in this stage. Fig 2 shows an example of the simulation of the power converter.

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IJEDST (2017), 5(1):1-6

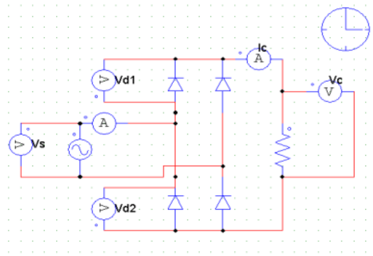

Fig.2. Simulation of an AC/DC converter

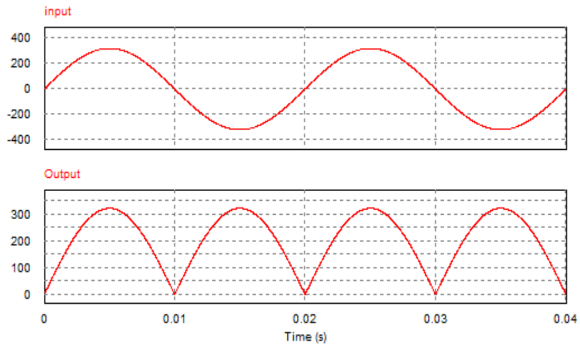

Fig.3. Input and Output Voltages

Fig 3 shows the input and the output voltage.

After the simulation of the power converter, the next step consists of the analysis of the power converter based on theoretical principles of the power semiconductor device.

Step 3: Analysis of the principle of working of the rectifier

The third step consists to the analysis of the principle of working of this rectifier. The instructor should motivate students to remember and think about the principle of working of the simple semiconductor devices which is the diode or the thyristor in this case. If the student knows that the diode is turned on when the potential of the anode is superior to the potential of the cathode, he will conduct a true analysis of the circuit. If else, the instructor should help these students to remember the working principle of the diodes.

Step 4: Experimental test of the rectifier and DC machine

The fourth step consists of the experimental test of the rectifier and the DC machine. Here, the student will connect all equipment, measure and visualize the voltages and the currents in different nodes and branches of the circuit. Fig 4 shows the experimental bench. The instructor and the students are free to do many exercises using this bench.

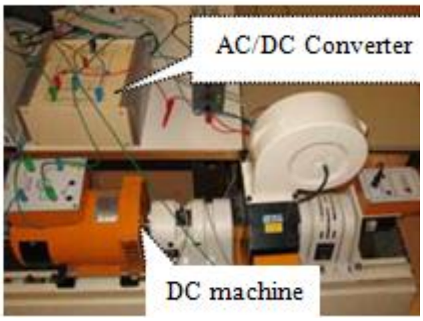

Fig.4. AC/DC converter with DC motor

Step 5: Theoretical analysis of other circuits of the rectifier

In aim to finish the course objective, the instructor will continue the analysis of some topologies of the rectifiers. In all parts of the course, students analyze, apply and interpret the operation of each converter. The instructor plays the role of the coach. He just helps students to think. Moreover, the student should construct the knowledge beginning by thinking about it.

Step 6: Comparison of the simulation results and experimental results to theoretical analysis

Before finishing the course all students will simulate all circuits analyzed previously. They will justify the results by applying their knowledge. The objective of this proposed step is to compare the simulation results to the experimental and theoretical results. The students use different ways to memorize the new knowledge. Another complementary work consists of the design of rectifier circuits for a given application like the speed control of DC motor or the control of the lamp light.

IMPROVING THE TEACHING BASED ON HIGH THINKING SKILLS

This section concentrates on the analysis of the proposed teaching method in the laboratory. In fact, this method uses different tools like computers, software, electrical machine and power converter. The analysis of the students' results shows the benefits of the proposed method on the students' skills and knowledge. However, the proposed method should be analyzed and compared to the learning methods based on high thinking skills. The objective is to improve the proposed method efficiency in the field of engineering education.

Necessity of the teaching based on high thinking skills

Learning and teaching based on high thinking skills were analyzed in more attention in the last decade.

In fact, this type of learning allows improving the graduates' skills.

Nowadays, every curriculum defines many higher order objectives. However, learning typically culminates in a set of lower order results. This is due to many facts. Indeed, many teachers make incompatible assumptions about knowledge with high order results. For each course, the instructor tries to accomplish all objectives. In this way, they forget the importance of the knowledge. However, when we sacrifice thought to gain coverage, we sacrifice knowledge at the same time. In fact, teaching each subject in such a way that students receive knowledge without thinking make possible that students leave the course with no sufficient knowledge. On other words, teaching using passive methods allows students forgetting the received knowledge. We commute an error when we define knowledge as though separated from thinking. Also, we often define knowledge as though gathered up by one person and transmitted to another in the form of a collection of sentences to remember. These definitions of knowledge exclude that knowledge by its self is produced and depends on thought. Indeed, the inventors produce knowledge by thinking. Also, the knowledge is analyzed and comprehended by thought. And finally the knowledge should be maintained and transformed by thought. If we keep in mind the relation between knowledge and thinking we accomplish all objectives at higher level skills. This allows us to narrow the gap between the goals and the results.

Analysis of the proposed teaching method

Due to the advantages of teaching based on high thinking, any new proposed method should take in consideration the necessity of high thinking skills in its steps of education. In aim to apply the learning based on high thinking skills the following recommendations are proposed for the new method of teaching:

•Phase 1: Thinking about the necessity of the knowledge:

In the phase when the problem is introduced, enough time should be given to students to think about the necessity of the knowledge. Hence, the students learn why to think in this first stage. In the example of the power converter, it is required that student think about the converter. If he proposed the solution, the recalling knowledge in previous situations and problems will be very easy for the student.

•Phase 2: thinking to identify the knowledge

During the second phase, the student will discover much knowledge about the solution. Indeed, using the required tools, the student will identify the input, the output and any others voltages or currents in the rectifier. Here the student learns how to think about the knowledge.

•Phase 3: thinking to analyze the knowledge

To memorize the knowledge in best way, the student should analyze the principle of the novel knowledge by applying previous studied laws. In this stage, the instructor plays the role of the coach. Indeed, all students in the group are invited to participate in the analysis and the interpretation of a given knowledge (the rectifier in the example)

•Phase 4: thinking to conduct the experimental test

The experimental activities are required in the field of engineering education. Usually students prefer to do the experimental test to touch equipment and tools. In this stage the student should think to connect all equipment. The instructor reacts by helping student and assuring safety for students and equipment.

•Phase 5: thinking to apply the novel knowledge The student thinks how to apply the novel knowledge in similar situations. Hence, the knowledge is applied in this phase.

•Phase 6: thinking by comparison of experimental and simulation results

The final phase has a great importance in teaching based on high thinking skills. In fact, the student regroups all his knowledge and skills in this phase. Usually working in groups, the students carry out different simulations and experimental tests. They attempt to do correctly the exercises and compare the obtained results. The instructor provokes students to think about the best method to do the simulation and the experimental and compare it to the theoretical. An important thing consists to that the student should identify what he know, what he needs to know (both information and methods), and what they need to do.

Results

The proposed instructional method based on high thinking skills is similar in many points of view to the problem-based learning. In fact, in all steps of learning the student think about the knowledge. In the same time, the instructor plays the role of the coach. Hence, this method can be easily addressed all learning outcomes and objectives of a given course.

The desirable skills and knowledge identified in engineering education were problem solving, equipment utilization and system simulation. A huge number of students in different successive terms participated in the case study. The results show good skills improvement that students made it. The students made significant improvements in self-directed thinking. They also demonstrated an ability to solve problems and use equipment similar to the equipment used in the course. On other hand, the method encourages the work in teams which allows increasing the skills in communication and team working. This case study offers pragmatic evidence of the efficacy of the proposed method of teaching and learning.

CONCLUSIONS

To improve the engineering education around the world, this paper described a novel method for teaching engineering. The method is based on high thinking skills to make good engineers. In all steps of learning the student turns around the novel knowledge. Moreover, the student is motivated to think how to think, why to think and what to think. Using this method, the student improves his skills in terms of experimental and simulation works. The results show the efficiency of the proposed method on both skills and knowledge of students. New teaching method based on the activities of students in industrial and technological environment will be proposed and discussed in next work.

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